CONVEYING THE COMPLEX: UPDATING U.S. JOINT SYSTEMS ANALYSIS DOCTRINE WITH COMPLEXITY THEORY

A Monograph

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ABSTRACT

CONVEYING THE COMPLEX: UPDATING U.S. JOINT SYSTEMS ANALYSIS DOCTRINE WITH COMPLEXITY THEORY, by Major Eddie J. Brown, 40 pages.

Complexity theory is an interdisciplinary set of concepts and tools that has proved useful for many fields and there is potential benefit for the military as well. Six concepts from complex adaptive systems theory—fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent phenomena—can improve social systems analysis in doctrinal operations processes. These in turn support four of the six commander activities—understand, visualize, describe, and assess—within U.S. Joint Force operations. The six concepts from complex adaptive system theory should be included with the existing general systems analytic methodology described in Joint Publication 2-01.3: *Joint Intelligence Preparation of the Operational Environment*, Chapter II, Section B, Part 12. This action is simply a start to updating Joint doctrine to account for complexity and this monograph recommends further research to identify and incorporate other tools from complexity theory for the U.S. Joint Force.

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ACRONYMS

JIPOE	Joint Intelligence Preparation of the Operational Environment
JOPP	Joint Operations Planning Process

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INTRODUCTION

Complexity theory is an interdisciplinary set of concepts and tools that has proved useful for many fields, from growing adaptive computer networks and urban models, to analyzing processes in social science and the human brain.[1] Given the interdisciplinary character of complexity theory and its utility for other fields, there is potential benefit for the military as well. The potential for benefit leads to the question: how could complexity theory apply to make the U.S. Joint Force more effective? What follows herein is an analysis of the potential of complex adaptive systems theory for U.S. Joint Force doctrinal operations processes. Some non-military processes—analogous to U.S. Joint Force operation processes—already employ complex adaptive systems theory and show promising potential. Incorporating complexity-based components into systems analysis can enable the Joint Staff to analyze and convey the complexity of the operational environment, improving operational understanding, visualization, description, and assessment by the commander.

A question that potentially encompasses all of U.S. Joint Force operations processes requires careful delimitation. Fortunately, an interesting commonality across U.S. Joint Force operations processes narrows the focus. Some central operations processes of the U.S. Joint Force make use of graphic social systems analysis. Social systems analysis appears in task organization, mission analysis, operational design, army design methodology, joint intelligence preparation of the operational environment, and intelligence preparation of the battlefield. Link diagrams, line-and-block charts, logic maps, and flow diagrams are all variants of social systems analysis. Social systems analysis is pervasive in U.S. Joint Force operations processes. A good place to seek

[1]Steven Johnson, *Emergence: The Connected Lives of Ants, Brains, Cities, and Software* (New York: Scribner, 2001), 21-22.

utility for complex adaptive systems theory in U.S. Joint Force operations processes then is social systems analysis.

A social systems analysis depicts the relationships between agents in a system.[2] Joint doctrine sometimes refers to agents as nodes, but agent is a less awkward term when dealing with social systems. Agents and relationships between agents are abstract concepts, which become more concrete within a particular frame of reference. An agent may be a person, a village, a staff section, an organization, or a nation-state as long as the agent behaves coherently within the frame. Agents have relationships with other agents. The relationships between agents have a physical connection and an exchange of some kind, usually a form of energy or information.[3] The exchange may be a grocery list sent by text message across the physical link of a cellular network, the diplomatic acknowledgment of a burgeoning nation through the appointment of an ambassador, or the derivative authority of golfing with the boss on Saturday. In social systems, agents conduct exchanges through relationships across physical means.

Complex adaptive systems theory offers some additional concepts relevant to social systems analysis. Complex adaptive systems theory is a particular theory synthesized by Scott E. Page in his undergraduate level course entitled *Understanding Complexity*.[4] In a more general sense, complexity theory is an expansive body of work that has gone by many names over the

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[2] Ludwig von Bertalanffy, *General Systems Theory: Foundations, Development, Applications* (New York: George Braziller, 1968), 195.

[3] Jamshid Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity* (San Diego: Butterworth-Heinemann, 2006), 83; Robert Axelrod and Michael D. Cohen, *Harnessing Complexity: Organizational Implications of a Scientific Frontier* (New York: Basic Books, 2000), 106-112. Axelrod and Cohen describe the dependence on energy or information, which when suddenly removed, is a possible source of shock for a system.

[4] Scott E. Page, *Understanding Complexity* (Chantilly, Virginia: The Teaching Company: 2009). This introductory course comes as a DVD and course notes for 14 lectures on complex adaptive systems.

years: nonlinear systems theory, the new sciences, and so on. To provide focus, this discussion treats Page's work on complex adaptive systems as a summative synthesis that encompasses the larger body of work related to complexity.

Page's work describes some unusual qualities that complex adaptive systems have, which are important because these qualities exist within the operational environment. First, complex adaptive systems exhibit emergence.[5] Emergence is a spontaneous, bottom-up creation of order and functionality. Example emergent phenomena include termite mounds, the layout of unplanned urban centers, and the neural activity that creates human intelligence. Emergent phenomena exemplify the axiom that the whole is greater than the sum of the parts. Such systems are also nonlinear and sensitive to feedback loops.[6] Feedback loops have circular cause-effect relationships, something like the chicken-and-egg thought experiment. Moreover, feedback loops may resist or amplify change in a system. Like a sound system, feedback loops may squelch a screech during a public address, or sustain and amplify it during a guitar solo. Since the systems are nonlinear, understanding cause and effect relationships in complex environments is extraordinarily difficult. Causality may come from an unknowable number of interdependent factors. Attempts to change such a system may have little effect, or worse, have a butterfly effect—a butterfly flaps its wings and causes a hurricane in another part of the world.[7] Military professionals will probably recognize these qualities as a description of the operational

[5]Page, *Understanding Complexity*, 21.

[6]Ibid., 27.

[7]Kerry Emanuel, *Edward Norton Lorenz 1917 – 2008* (Washington D.C.: National Academy of Sciences, 2011), 18. http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/lorenz-edward.pdf (accessed 10 September 2013). The butterfly effect specifically refers to a non-linear system's sensitivity to initial conditions.

environment. Similarities aside, does complex adaptive systems theory apply to social systems in a strict sense?

According to Page, a system is a complex adaptive system if its agents have four qualities: diversity, connection, interdependence, and adaptation.[8] Social systems have these four qualities. People and the groups they create are diverse, have connections with others, depend on one another, and learn and adapt to their environment. While it is sometimes helpful to take a simplified point of view of human social interaction, social systems are inherently complex adaptive systems.

Understanding social systems as complex adaptive systems brings some interesting concepts to the discussion, many of which can be helpful in social systems analysis. The six concepts from complex adaptive theory harnessed for this research are fitness landscape, agent fitness, agent response profile, building blocks, identity tags, and emergent phenomena. A brief description of each concept follows.

A fitness landscape is a metaphor of sorts related to the Darwinian idea of survival of the fittest.[9] Some agents are fit enough to make the cut and survive in a particular place, while others are not and die out. However, the cut line for fitness changes from place to place. In some places, the cut line is low, like a valley, and living is easy. In others, the cut line is more like highlands, and survival is difficult. The cut line of fitness changes from place to place and traces a three-

[8]Page, *Understanding Complexity*, 4. Complex adaptive system agents must possess of each of these four qualities without having too much. Page and other complexity theorists call this “the interesting in between,” where the volume knob for the qualities is neither at 0 nor 10.

[9]Ibid., 6. Page’s description of fitness landscapes inspires but differs slightly from the description here. Page uses fitness landscapes as a metaphor for success, where this argument uses them as a failure line for natural selection. The ideas are two sides of the same coin: success as not failure.

dimensional surface, like elevation does on a landscape. Agents fit enough to remain on or above the landscape live on, while those that slip below it end up dead and buried.

The fitness landscape can be a dangerously unpredictable place for agents. Not only does the landscape bury those agents not fit enough, it can undulate.[10] A fitness landscape's elevation varies in time as well as place, which causes the undulation. Unwary agents may find their once comfortable position suddenly dangerously close to a landscape changed by the interacting relationships in a system.

Agent fitness is how well the agent is doing in relation to the fitness landscape.[11] The safest place to be is as far away from the fail-line as possible, and some agents manage to do quite well on the fitness landscape. Very fit agents may be far away from the survival cut line and are metaphorically flying above the landscape. The factors that measure agent fitness are identical to the factors that make up the fitness landscape. In some valleys on the landscape, the fitness level required may be low, living is easy, and many agents can survive there. In highlands, only the fittest agents can make it. Since survival is at stake, agents typically attempt to maximize their relative fitness.

An agent response profile is the decision-making and option exploration behavior an agent employs to maximize fitness.[12] Every agent makes choices and pursues goals, which may

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[10]Page, *Understanding Complexity*, 6-8. Page describes the undulation of the fitness landscape as dancing.

[11]John H. Miller and Scott E. Page, *Complex Adaptive Systems: An Introduction to Computational Models of Social Life* (Princeton: Princeton University Press, 2007), 81-3. The authors do not explicitly state what might motivate agents to adapt. This discussion assumes there are implied measurable qualities for agents, collectively called agent fitness, that correspond to the fitness function and drive the need for agents to adapt.

[12]Henry Mintzberg, *The Rise and Fall of Strategic Planning: Reconceived Roles for Planning, Plans, Planners* (New York: Free Press, 1994), 55. From M. E. Porter, *Competitive Strategy: Techniques for Analyzing Industry and Competitors* (New York: Free Press, 1980), 49. Porter's response profile inspired the naming convention for the bounded, contextually reactive

or may not work out for the agent. Culture, perception, emotions, and perhaps even decision matrices shape these choices and goals. Yet these things that shape an agent's behavior tend to change slowly, leaving the agent with some guidelines for behavior, perhaps even a set of rules they follow. Whether deliberate choices or just going with the flow, an agent's behaviors are indications of a response profile.

Building blocks are the working material of adaptation within agents, which are exchangeable and transferable among agents.[13] These blocks help form an agent's response profile. Think of several children passing building blocks back and forth and building plans between one another while each attempts to build the very best toy. Although, in this case the giver makes a copy of the block before passing it to the receiver, so the giver does not lose the shared block. Agents with a wider array of building blocks and plans have a greater chance of having the one they need and a therefore better chance of building a better toy.

Identity tags then help agents decide with whom to share: birds use colored feathers to find mates, people in business use watches to establish credibility, and gangs in Los Angeles wear red or blue clothing to show allegiance.[14] In some places a proper hairstyle, a scarf a certain length, or speaking in a certain accent are important identity tags. The idea can go a step further

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decision-making described here, although his definition and the use here are not necessarily the same. The word strategy, a familiar alternative for some, is not used for three reasons. One, the word strategy comes with a lot of etymologic baggage. Two, psychologists offer that people often see themselves as reacting to context, rather than having a quality or pursuing a strategy. Three, to examine agent behavior as a reaction to context is more helpful when looking for opportunities to modify that behavior.

[13]John H. Holland, *Hidden Order: How Adaptation Builds Complexity* (New York: Basic Books, 1995), 34.

[14]Holland, *Hidden Order*, 14. Anthony R. Pratkanis and Elliot Aronson, *Age of Propaganda: The Everyday Use and Abuse of Persuasion* (New York: W. H. Freeman, 2001), 216. Pratkanis and Aronson explain the arbitrary assignment and utilization of identity tags as granfallooning.

in agents identifying one another. Telephone numbers, e-mail addresses, internet protocol (IP) addresses, and media access control (MAC) addresses can also be identity tags. Identity tags help spark relationships between agents. Agents display and examine each other's identity tags to help establish or reestablish relationships. They are a sort of social *bona fides* for interaction selection.

The last concept from complex adaptive systems theory for discussion here is emergent phenomena.[15] Emergent phenomena happen from the bottom up in a system without formalized control. No one is in charge directing the system's behavior, but the system of relationships and interactions ripple throughout to create system behaviors. Examples include anthills and human sentience. Witnessing inexplicable emergence is sometimes the first sign that something unusual is going on and that complexity exists in a system. In many instances of social systems analysis, the analysis starts with an emergent phenomenon as a system behavior of interest. The emergent phenomenon then serves as the frame of reference for subsequent analysis. It falls upon the analysts to understand and explain the conditions that result in the emergent phenomena.

Stepping back from the six concepts of complexity for a moment, how is one to judge the effectiveness of including the concepts in Joint social systems analysis? Evaluating the quality of analytic processes—with or without complex adaptive systems concepts—can be very challenging. Evaluation criteria can help, but selecting meaningful criteria is important for having meaningful evaluation. This discussion returns to the intent of conducting systems analysis in the first place to draw out some evaluation criteria. Analysis ought to help commanders make informed decisions. The efficacy of analysis links to decision-making through the operations process and better analysis processes enables more informed decision-making in the U.S. Joint Force.

[15]Page, *Understanding Complexity*, 21.

The U.S. Army's decision-making doctrine outlines six commander activities in the operations process: understand, visualize, describe, direct, lead, and assess.[16] Some of the six rely more directly on analytic processes than others. Two that are less reliant are directing and leading, which derive information from the other activities and often do not require direct analytic support. However, the other four commander activities—understand, visualize, describe, and assess—do rely heavily on analysis processes. Therefore, the commander activities provide a meaningful way to evaluate analytic processes. For clarity, a description of the four criteria follows.[17]

Understanding is doctrinally the first commander activity in the operations process. Although it comes logically first, it is an ongoing activity throughout the operations process and the subsequent operations. Understanding includes establishing context—the set of circumstances that surround a particular event or situation—so a commander may grasp the nature and significance of the operational environment. Understanding reduces uncertainty, guides research and analysis by identifying unknowns, helps identify certain uncertainty, anticipates higher-order response effects, and identifies risk. Better understanding also leads to better visualization.

Visualization is the next commander activity in the operations process. Visualization may be a deliberate, explicit activity by a commander, or may be intuitive. Visualizing includes defining a desired end state and envisioning an operational approach to achieve it. The results of command visualization may be broad and sketchy, detailed and finely polished, or anywhere in between. Regardless, visualization facilitates the development of options, reveals targetable aspects within a system, and is useful across many frames of reference. Once visualizing is

[16]Department of the Army, ADP 5-0: *The Operations Process* (Washington D.C.: Headquarters, Department of the Army, 2012), 1.

[17]Ibid., 2-4. A description of all four commander's activities is included in these three pages of the publication.

complete and an operational approach and commander’s intent takes shape, one must describe the visualization to others.

Describing includes communicating a shared understanding and purpose to ensure everyone involved understand a particular visualization well enough to begin course of action development. No organization can execute an operational approach or course of action well if the organization does not understand it well first. Driven by the iterative nature of understanding and visualizing, describing is also iterative. The multitude of warning orders, operations orders, and fragmentary orders for a single operation demonstrate the iterative nature of describing. Consistent collaborative communication is important for this activity, making use of clear and expected outputs. With description comes action and an assessment of the action’s results naturally follows.

Assessing includes understanding current conditions and determining how the operation is progressing to anticipate and adapt to changing circumstances. Although listed last here, Joint doctrine shows assessment as an activity that exists from beginning to end in the operations process.[18] A good assessment enables comparison of the anticipated versus the actual for both performance during operations and effects of operations. To continue the theme for the commander’s activities, assessing—like understanding, visualizing, and describing—occurs iteratively and continuously.

By employing the select four command activities as evaluation criteria, this discussion can evaluate analysis and operations processes associated with analysis based upon outcome. Analysis means little without decision. The outcome of better analysis processes is more informed decision-making. The outcome of doctrinal processes is difficult to measure

[18]Department of Defense, Joint Publication 5-0: *Joint Operation Planning* (Washington D.C.: Headquarters, Department of Defense, 2011), IV-3.

quantitatively, but comparing descriptions of processes before and after is feasible. To deal with this difficulty of measurement, the evaluation of U.S. Joint Force operations processes herein will employ the four criteria in a subjective, qualitative manner.

The introduction closes with the groundwork for the discussion established. This discussion will use four evaluation criteria—understand, visualize, describe, and assess—to evaluate how six concepts from complex adaptive systems theory—fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent phenomena—might help make social systems analysis in doctrinal processes better. Next is an examination of how the U.S. Joint Force processes employ social systems analysis and how elements of complexity theory are already a part of operations processes.

SOCIAL SYSTEMS ANALYSIS IN DOCTRINE

Before considering complex adaptive systems theory for the joint operations planning process (JOPP), what sort of social systems analysis does the U.S. Joint Force do in the JOPP? The JOPP has an astonishing number of processes that compose the overall planning process.[19] However, three central processes use social systems analysis. First, the joint intelligence preparation of the operational environment (JIPOE) provides information about the context for operations. Next, operational design defines the operational problem and formulates an operational approach to solve the problem. Finally, the joint personnel planning process develops capability through a Joint Force structure to solve the problem. Each process uses social systems analysis slightly differently.

[19] Department of Defense, Joint Publication 5-0, IV-3.

The JIPOE offers a node and link methodology to construct a systems perspective of the operational environment.[20] The nodes are agents and the links are relationships in social systems analysis. The systems analysis method in the JIPOE includes constructing three-dimensional diagrams of nodes and links across six subdivisions of the operational environment, analyzing relationships, and evaluating their impacts on military operations. If analysts follow the methodology in the JIPOE, the resulting understanding of the operational environment should help the operational planners visualize and describe an operational approach in the operational design process.

Operational design employs the systems analysis from JIPOE as a tool to first understand the operational environment, and then visualize and describe an operational approach. The operational design process defines the problem and develops an operational approach by asking and answering the questions of where we are, where we are going, and what prevents us from going where we want to go?[21] *Where we are* is an understanding of the current state of the system. *Where we want to go* is the desired state of the system. *What prevents us from going where we want to go* is change the Joint Force must make in the system to reach the desired state for the system. The operational approach that results is a sequence of actions to achieve the desired state of the system.

The actions planned for in the operational approach must have the right resources to generate capability. Where a fighter jet is a resource, the resource becomes a capability with a pilot, ground crew, airfield, hanger facility, and so on. The same requirement applies to tanks, ships, and rifles. Capability is what can accomplish change in the operational environment. While

[20]Department of Defense, Joint Publication 2-01.3: *Joint Intelligence Preparation of the Operational Environment* (Washington D.C.: Headquarters, Department of Defense, 2009), II-44.

[21]Department of Defense, Joint Publication 5-0, III-3.

other planning efforts within the JOPP play important roles, ultimately the people within the Joint Force turn the many kinds of equipment resources into capability.[22] For this reason, the Joint personnel planning process is where resources generate capability in the JOPP.

The joint personnel planning process organizes a tailored U.S. Joint Force for effective and efficient employment.[23] Joint personnel planning produces, among other products, a line and block chart for the Joint Force. Although not obvious, these line and block charts from the joint personnel planning process are a social systems analysis. The blocks of the chart represent the people and equipment organized under a headquarters and are the agents in the system. The lines represent command relationships between the headquarters and are the relationships between the agents.

Looking back across the three central JOPP processes, social systems analysis occurs in all three. The Joint doctrine explicitly calls for social systems analysis in the JIPOE, and tacitly requires it for operational design and personnel planning. The interaction of the social systems analysis from the JIPOE, operational design, and joint personnel planning is important for the JOPP. When all three subordinate planning processes combine, the Joint Force system generates the capability to change the operational environment to the desired system state through the operational approach. This summative paragraph answers what sort of social systems analysis the U.S. Joint Force does in the JOPP, but how well does it work?

Evaluating a doctrinal method for planning can be difficult. The reason for the difficulty is that observable instances of pure doctrinal processes are rare if not nonexistent in the military. Doctrine, while apparently directive, is actually more a common point of departure. An individual

[22]Department of Defense, Joint Publication 1-0: *Joint Personnel Support* (Washington D.C.: Headquarters, Department of Defense, 2011), cover letter.

[23]Ibid., xi.

organization will often couple doctrinal processes with local best practices and norms to create a planning process unique to the context at hand. The unique quality of actual versus doctrinal processes forces an indirect approach to evaluating the JOPP. Given the need for an indirect approach, the evaluation of the JOPP that follows here presents a hypothetical failure-mode analysis of the process. The evaluation will include probable shortcomings of the JOPP as doctrine describes it.

The social systems analysis methodology in Joint Publication 2-01.3: *Joint Intelligence Preparation of the Operational Environment*, Chapter II, Section B, Part 12 is generally a good news story for the Joint Force. The nodal analysis used in the JIPOE is a helpful way to understand, visualize, describe, and assess the realities of the operational environment. An analyst can understand a great deal about the richness and complexity of a situation by constructing association matrices and network analysis diagrams to identifying key nodes in it. How do people interact with one another? What benefits do the individuals get from relationships? What kinds of behaviors can one expect from a certain people under a set of interacting circumstances? How might the situation change when stressed by military operations? General systems theory—and the U.S. Joint doctrine on which it is based—has helped answer these questions to the benefit of commanders and their staffs.

The bad news is that node and link diagrams do not always capture the full extent of the understanding of reality the analyst develops during the JIPOE. Often, the goodness of the JIPOE is in the construction of the products and not always in the products themselves. Once constructed, the diagram cannot communicate all the information learned by the analysts during the diagram's construction. Furthermore, as a model of the messiness of reality, the analytic products may be equally messy and confound those who did not participate in their development. Further reducing the efficacy of the analyst's work, the digital transmission of analytic products with limited staff interaction with analysts is the norm. The Joint Staff, which is often very large and dispersed, may not have the opportunity to brief their own analysis products. If the analyst is not available to explain the product, then the social systems analysis done during JIPOE may not convey the full understanding of the operational environment.

The limitation of products to convey understanding is worse in the joint personnel planning system. Task organization charts have the same challenges as the JIPOE nodal analysis but add another. The links between nodes on a task organization chart only represent command relationships. The relationships between staff sections and subordinates are clearly much more rich and robust than simple command relationships. The problem dictates a typical solution: new organizational members without experience in the organization must often take time to explore their surroundings simply to understand the social system of which they are now a part. Without the right experience, the task organization products from the joint personnel planning process do not provide clear understanding of the capabilities of a Joint Force.

Both the limited ability to transfer understanding from the JIPOE and the joint personnel planning process to the operational design team can carry over into operational design products. Doctrinally, operational design interacts through an iterative dialog with the JIPOE, personnel planning, and several other doctrinal processes.[24] The operational design team ought to be able to start with the operational environment analysis, apply the Joint Forces capability analysis, and visualize probable changes in the environment. Design teams must typically reach broadly across the organization and bring in additional team members to mitigate the risk of incomplete understanding, but did the design team bring in the right team members? Was the analyst or staff member that developed the analytic product identified, available, and present at the critical, time constrained moment? Sometimes the answers are yes. Sometimes they are not. An incomplete understanding of *where we are* can lead to a faulty visualization and description of *where we*

[24]Department of Defense, Joint Publication 5-0, III-8, 12, 14.

want to go, and assessing *are we there yet* can become difficult for the Joint Force staff and commander.

Stepping back from the hypothetical and perhaps typical narrative of social systems analysis in the JOPP, how does the narrative stack up against the evaluation criteria of understand, visualize, describe, and assess? Recall that understanding is the first commander activity in the operations process and includes establishing context to grasp its nature and significance to reduce uncertainty, guide research by identifying unknowns, help identify certain uncertainty, anticipate higher-order response effects, and identify risk. The process of passing incomplete and confounding analytic products from staff section to staff section in an organization fails to adequately connect analyst and staff members to the commander, reducing understanding and increasing risk. As the staff section with the most direct access to the commander, the operational design team must often pick up the slack and fill in the gaps, at best repeating and recreating the work done elsewhere in the organization.

The doctrinal JOPP can also poorly inspire a commander's visualization. Visualization should facilitate the development of options, reveal targetable aspects within a system, and be useful across many frames of reference. The social systems analysis in the JIPOE has only two concepts to express the richness and variety of the agents and their relationships in the operational environment. The Joint personnel planning process has a similar limitation, but extends it a step further by reducing the agents to subordinate organizations and command relationships only. Neither depicts the rich detail of the environment or the Joint Force's capability to affect it. Once again, the design team—and perhaps the commander—must fill the gap.

Once the analysis process fails to enable the command activities of understand and visualize, one can assume the describe activity will continue to diverge from any reliance on analytic products. Why should one expect analysis to enable the describe activity if it failed to provide understanding or the ability to visualize? Process failure can cause the iterative and collaborative nature of the operations process to be less effective, meaning commanders and the analysts and staff meant to enable them can begin to diverge. In such a situation, the risk of a commander coming uncoupled from her analytic support increases, which in turn can increase operational risk.

Assessing is a command activity that exists from beginning to end in operations processes and ineffectual analytic processes affect it from beginning to end as well. Without a good analytic assessment of current conditions, the commander (and perhaps the design team) must determine how the operation is progressing to anticipate and adapt to changing circumstances without the assistance of the analytic processes that should enable them. Once again, risk increases.

The preceding survey of doctrinal limitations runs a thread through a common problem throughout the JOPP: the limitation of node and link analysis in conveying to the commander the fullest understanding developed by analysis. Although researching and creating general systems theory-based node and link analysis products helps the analyst, the analytic products themselves may not capture and communicate the understanding to others. By failing to communicate the fullest possible understanding through analytic processes to the commander, the subsequent commander's activities suffer and operational risk increases.

Perhaps capturing and including more pertinent information in existing analytic products could help the problems of social systems analysis in the JOPP. The additional information should not be simply more, but should include information linked to understanding, visualization, description, and assessment. Including such pertinent information in analysis processes and products could then enable better communication and consistency from the analyst, through the operations process, and ultimately to the commander. Complex adaptive systems theory offers six concepts—fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent phenomena—that could be used as forms of information to include in analysis processes and products to make social systems analysis in doctrinal processes better.

The idea of complex adaptive systems theory helping military operations processes is not so farfetched. Concepts from complexity theory have already helped the military. In 1996, a researcher at the U.S. Center for Naval Analysis, Alexander Ilachinski, published an eight-tiered applicability model for complex systems theory in land warfare. The tiered applications ranged from the conceptual use of metaphors to think about the complexity of warfare, to synthetic modeling of combat environments and the development of technological applications. The report sparked interest with senior military leadership and created opportunity for further exploration of the utility of complexity theory by posing nine open research questions.[25] The nine questions posed by Ilachinski and the attempts to answer them since—whether explicitly or incidentally—have provided a basis for the revision of military doctrine by the U.S. Army, U.S. Marine Corps, and the Australian Army.[26]

Complexity theory has inspired a paradigm shift for both military analysis and operations. Perhaps more accurately, complexity theory helped to shift the paradigm back to that of Sun Tzu and Carl von Clausewitz.[27] For these two theorists, warfare is composed of interacting

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[25]Alexander Ilachinski, "Land Warfare and Complexity, Part II: An assessment of the Applicability of Nonlinear Dynamics and Complex Systems Theory to the Study of Land Warfare," (Alexandria: Center for Naval Analysis, 1996), 122-5. http://www.cna.org/research/ 1996/ land-warfare-complexity-part-ii-assessment (accessed 8 July 2013).

[26]Alex J. Ryan, "Military Applications of Complex Systems," in *Handbook of the Philosophy of Science: Philosophy of Complex Systems*, ed. Dov M. Gabbay, Paul Thagard, and John Woods (San Diego: North Holland, 2011), 749.

[27]Roger T. Ames ed. and trans., *Sun Tzu: The Art of Warfare* (New York: Ballantine Books, 1993), 76, 79; Carl von Clausewitz, *On War* (Princeton: Princeton University Press, 1976), 89. On page 76 of Ames, "The constant shifting disposition of any thing or event is constituted in tension with environing others, where their dispositions condition one's own." On page 79 of Ames, "Battle then is simply one disposition trying to prevail over another. All distinguishable dispositions can be prevailed over. The problem lies in knowing which

relationships and is full of uncertainty. Complexity theory has helped reassert that warfare is difficult to predict in the detail as commanders might wish.[28] Too often, a theoretical advance in science has heralded the assertion that warfare can now be controlled or predicted in some way.[29] From geometric theory for military lines of operations to the application of general systems theory for the ill-fated effects based approach to operations, the application of scientific theories offers no panacea for warfare.

Neither theory nor technology can make warfare perfectly predictable and controlled. Complexity theory has helped explain why this is so. Yet the theory might also be helpful if applied carefully. Complexity theory has already helped make some other operations processes in the military better. Perhaps complexity might help analysts, staff members, and commanders with the common problem throughout the JOPP: the limitation of node and link analysis in conveying the fullest understanding possible of a social system. Regardless of any perceived potential, a theory ought to be applied to military operations processes with a healthy skepticism. To avoid proceeding too boldly, an examination of how the six concepts from complex adaptive systems theory have helped elsewhere is in order.

HELPFUL COMPLEXITY THEORY

The introduction defined six concepts from complex adaptive systems theory—fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent

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disposition will enable one to prevail." Paraphrasing Clausewitz, warfare's trinity is the tension between primordial violence, probability, and policy. The tension between the three creates the conditions for warfare to occur. One interpretation of the trinity is the primordial violence is the will of the people, the probability is the realm of the commander, and policy is the responsibility of the government.

[28]Ryan, "Military Applications of Complex Systems," 749.

[29]Bousquet, Antoine, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York: Columbia University Press, 2009).

phenomena—to attempt to make social systems analysis in doctrinal processes better. Before simply applying these six concepts to social systems analysis in the JOPP, how has each of these concepts helped processes analogous to U.S. Joint Force processes? The following three examples present ways others have employed complexity-based concepts in analysis. The first example looks at a social game with and without concepts from complex adaptive systems theory; the second shows the benefit of including the concepts in a process similar to operational design; and the third takes a hard look at successes and failures of complex adaptive systems theory in information systems.

Building a Better Dilemma

A warm up example involves a well-known social game called the iterative prisoner's dilemma.[30] The situation in the game is two people, prisoner A and B, who have committed a crime together. They are now in the custody of the authorities. The authorities suspect both A and B of committing the crime, but do not have the evidence to convict either one. The prisoners are in separate cells where neither can communicate with the other and the each faces a stiff punishment. If prisoner A defects (confesses and implicates B) then the authorities will have the evidence to convict B and will offer a lesser punishment to A. Prisoner B has the same option. If both defect, then the authorities have the evidence to convict both, but both will get the lesser punishment. If neither A nor B defect (neither confesses) then the authorities have no evidence and must let both go free. The game then iterates to allow A and B to once again choose to defect or not. The game and its variants provide a convenient springboard to examine social science ideas. For this discussion, it offers a way to demonstrate the concepts of social systems analysis and to examine the potential of complex adaptive systems theory.

[30]"Prisoner's Dilemma," *Stanford Encyclopedia of Philosophy* (2007). http://plato. stanford.edu/entries/prisoner-dilemma/ (accessed 05 June 2013).

A basic social systems analysis of the game depicts the relationships between agents in a system whereby the agents exchange energy and information. The three agents are prisoner A, prisoner B, and the authorities. The relationship between prisoner A and B was formerly as cooperating criminals, but the authorities placed each in a separate cell severing that relationship. Prisoner A and B can no longer collaborate to cooperate. The authorities have established their own respective relationships with prisoner A and B in which the prisoners may exchange information about their crime for the energy—in the form of punishment—from the authorities. From a basic social systems analytic point of view, each prisoner faces a dilemma with very limited options and the game becomes straightforward. Regardless of the iterative choices made by the other prisoner, each prisoner will be better off defecting every time.[31]

The result of basic social systems analysis for the game can be unsatisfying and unrealistic. Often, the first time a person hears the prisoner's dilemma and its basic-social-systems answer, some sort of rebuttal follows the furrowed brow. Political scientists, psychologists, and other anthropological professionals have dutifully studied why the answer to the game is not consistent with observations of real human social situations.[32] A gang member could probably just as quickly tell you why he would not sell out his friends. While an academic's explanation may seem substantively different from that of a criminal, the wide range of responses share a commonality. There is more going on in the system than basic social systems analysis can understand, visualize, describe, and assess. With such a simple game, computer simulations can be helpful in illustrating some of what may be missing.

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[31]Without the concept of a response profile, the analysis cannot capture the experiential learning done by A and B with regard to past defections.

[32]Axelrod and Cohen, *Harnessing Complexity*, 95-100.

Rick L. Riolo has run many computer simulations based on the game of the iterated prisoner's dilemma.[33] His simulations had the basic social systems concepts of agents and relationships, but he added agent fitness, agent response profiles, building blocks, and identity tags. Agent fitness was the measure of reciprocal altruism, meaning agents sought other prisoners to pair with that would not confess. The response profiles of the agents were composed of building blocks of rules for interaction, with agents acting in a tit-for-tat (do unto others…), meanie (always defect), or sucker (never defect) fashion. The identity tags were simply a 0 or 1, but the agents were biased in their response profiles towards other agents with like tags.

Within ten or more iterations, the simulations with identity tags showed agents breaking from the simple defection solution and forming clusters of cooperating agents based on identity tags.[34] Cooperation based on neighborhoods of self-similar people mimics the spontaneous behavior of society and is much more intuitively satisfying than the more basic answer of always defecting. More intriguing, the average fitness of agents using identity tags was higher and had less deviation during relative systemic highs and lows, which is similar to the human experience of altruism in groups. More cynically though, there was a cyclic nature to the formation, temporary success, and then dissolution of the neighborhoods, as too many cooperating suckers made exploitation by a meanie inevitable.[35]

The simulation results also demonstrate the concepts of emergent phenomena and fitness landscape. Emergent phenomena happen from the bottom up in a system without formalized

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[33]Rick L. Riolo, "The Effects and Evolution of Tag-Mediated Selection of Partners in Evolving Populations Playing the Iterated Prisoner's Dilemma," Santa Fe Institute Working Paper 1997-02-016 (November, 1996), http://www.santafe.edu/research/working-papers/abstract/e9874bbf6831dcff502b7211f8302a33/ (accessed 05 June 2013), 1.

[34]Ibid., 11, 13.

[35]Ibid., 10, 14.

control. No single agent was in charge after the simulations started, to include Mr. Riolo. After the initial set up, the system of relationships and interactions rippled through to create aggregate system behaviors. Some agents were fit enough to make the cut, survive, and reproduce in a particular place, while others died out. The cut line for fitness changed based on the interaction of the agents. Once a neighborhood formed, the fitness of the clustered agents was well above the cut line. However, the fitness landscape was dangerously unpredictable, effectively dancing as meanies moved in the middle of sucker clusters and destroyed the neighborhood. The simple game was now more complex, interesting, and—arguably—intuitively satisfying. More importantly, it more accurately reflected reality.

The computer simulations Mr. Riolo conducted were a study of adding concepts from complexity to a simple social game. He was careful to avoid sweeping conclusions about society's use of tags, yet observed that including the concepts from complexity in the game "can dramatically change the dynamics of populations of individuals."[36] Even with rudimentary response profiles in a simple competition, relationships can bring about stimulating observations of emergent phenomena. The results of the iterative prisoner's dilemma simulations with the additional concepts from complex adaptive systems were more consistent with observations of human social situations. Including the concepts in social systems analysis could similarly improve an analyst's ability to understand, visualize, describe, and assess such systems.

Emergent Health Care

A second example demonstrates an ongoing attempt to use complex adaptive systems concepts to understand, visualize, describe, and assess health care systems. The health care system in the United States has its fair share of problems related to the complexity of the system.

[36]Riolo, "The Effects and Evolution of Tag-Mediated Selection of Partners in Evolving Populations Playing the Iterated Prisoner's Dilemma," 29.

The quality of individual physicians and the relationships between patients and their physicians continue to be generally good. However, high rates of medical error and low quality of care continue to be problematic.[37] In 1998, a health care quality consultant named Helen Harte helped organize a course, which became the Managing Complex Organizations executive education course in 2001, meant to help health care executives cope with the complexity of the health care system.[38]

The program is composed of four parts—Patterns, Possibilities, Organizational Ecology, and Leadership—which run parallel to the military's operational design. Part I: Patterns seeks to develop an understanding of the behavior of the organization, which corresponds to operational design's question of *where we are*. Part II: Possibilities seeks to visualize an alternative state for the organization, which corresponds to operational design's *where we want to go*. Part III: Organizational Ecology seeks to promote organizational change, which is similar to the operational approach that comes as an output from operational design. Finally, Part IV: Leadership is an examination of the role of the individual—executive, physician, or pharmacist—in the organization to create the objectives and structure to accomplish change. The similarity between Part IV and the military's roles for leadership is clear.[39]

Where the Managing Complex Organizations course differs from operational design is in its application of complex adaptive systems concepts for analysis. The kind of analysis the course does involves a fitness landscape for patients composed of doctors, specialists, pharmacists,

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[37]Yaneer Bar-Yam, *Making Things Work: Solving Complex Problems in a Complex World* (Cambridge: NECSI Knowledge Press, 2004), 115.

[38]New England Complex Systems Institute, "Overview," *Managing Complex Organizations: A Two-Day Executive Education Program* (2013). http://www.necsi.edu/education/executive.html (accessed 10 June 2013); Bar-Yam, *Making Things Work*, 113.

[39]Department of Defense, Joint Publication 5-0, III-3; Bar-Yam, *Making Things Work*, 114.

administrators, insurers, and employers. The interaction of the respective agent fitness, agent response profiles, building blocks, and identity tags helps to form both a large-scale health care system and many subsystems of care.[40] Health care for an individual is not a simple event, like an emergency room visit or doctor's appointment. Health care is actually an emergent phenomenon of a health care system. It comes from the interaction of the patient's physician in concert with a multitude of other professionals in the health care system.

By educating health care executives to the complex adaptive health care system, the executives could not only understand, visualize, describe, and assess the system better, but also could lead and direct within the system with more confidence. Participants have offered testimonials such as, "When dealing with daily technical and management issues you often lose perspective on the richness of the organizational environment. This session has given me the space to appreciate that and learn some things to help me cope with it." Although one might think understanding the world through complexity would be just as complex, one testimonial offered, "My understanding of the complex world has now been greatly simplified."[41] Ultimately, the education process offered by the Managing Complex Organizations course helped establish not only new education requirements for health care executives, but resident physicians as well. The physicians, as the frontline of the health care fight, needed to understand the complexity of the health care context to provide better patient care.[42]

This health care example demonstrates the improvement of a process similar to operational design when participants—medical executives and care providers in this case—

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[40]Bar-Yam, *Making Things Work*, 125, 129, 139, 152-3.

[41]New England Complex Systems Institute, "Testimonials," *Managing Complex Organizations: A Two-Day Executive Education Program* (2013). http://www.necsi.edu/education/executive.html (accessed 11 June 2013).

[42]Bar-Yam, *Making Things Work*, 115.

consider concepts from complexity. It highlights the role of educating participants in concepts from complex adaptive systems for social systems analysis. The military has similar education efforts for complexity within selective field grade officer professional military education courses.[43] However, the education of top-tier management is not the one-size-fits-all answer for coping with complexity. Even complexity-educated executives and officers must rely on analysts and analytic processes for decision-making support, especially in military operations.

Risk in Information Systems

A third example is an analysis of successes and failures in information systems. The successes demonstrate the potential for complex adaptive system theory's utility, while the failures are reminders of the dangers of overconfidence in analysis. Large information systems are complex adaptive systems composed of pathways, routers, servers, computers, technicians, and—a challenge to technical support staff on the best of days—users. The software, hardware, and user behaviors are building blocks that form response profiles for the agents. The various user identities, addresses, and metadata within information packets provide the identity tags for information flow and interaction. As is the case in many analytic framing examples, the fitness landscape and agent fitness within information systems varies according to the emergent phenomenon one wishes to analyze. Complexity has helped make information systems perform better and in powerful ways in the information age, but examining information systems with and without concepts from complexity would not offer any insights that the previous examples have not already highlighted. More important for this discussion is the insight they offer for understanding and analyzing risk in a complex operational environment.

[43]The U.S. Army School of Advanced Military Studies' Advanced Military Science Program teaches a small sampling of complex system theory during the six-week Design of Operational Art block of instruction.

Although not a purely human system since machines mix with people, information systems are worth examining to understand risk analysis in social systems. Every system is subject to stresses that can cause failure—the fall of Rome comes to mind—and information systems are no exception. However, where human systems can be difficult to examine historically and conducting multiple iterations of them are impossible, information systems are easier to examine and they may iterate quite often. Information systems can also provide lessons with fewer political and ethical implications for data collection and study. More importantly, both information systems and human systems tend to evolve faster than historical information comes available about the new system.[44] As a result, analysts must examine risk for both information and human systems based off something other than empirical data.

The overarching trend in risk analysis in the absence of empirical data is the tendency to identify and mitigate the immediate problem, only to unintentionally cause new ones. A stepped examination of risk analysis demonstrates the trend. The first step is human intuition. Intuitive risk analysis is the tendency to deal with problems on an ad hoc basis and is clearly better than ignoring risks altogether. Intuition works fine for some problems, but intuition can miss risks that seem obvious with the advantage of hindsight.[45] The assumptions made by the pioneers of what would become the internet and the risks linked to those assumptions are indicative.

The revolutionary new information system called the internet, realized by Advanced Research Projects Agency of the U.S. Department of Defense, was a "concept where everyone on the globe is interconnected and can access programs and data at any site from anywhere."[46] The

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[44]Axelrod and Cohen, *Harnessing Complexity*, 106.

[45]Dietrich Dorner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations* (New York: Basic Books, 1996), 4-6.

[46]The Computer History Museum, "Internet History," *Exhibits* (2004). http://www.computerhistory.org/internet_history/ (accessed 11 June 2013). This is a quote from

implied assumption made by the founders is that only likeminded, intellectual, and altruistic people would take part. Vandalism, fraud, identity theft, and pornography have been part of human culture for a long time, and internet users have been exposed to them as well. The unidentified risk from morally casual users may be obvious now, as contemporary information systems architects speak almost reflexively of security. In an effort to avoid missing the obvious with intuition, systems analysis offers a more advanced analytic technique.

General systems analysis tends to be better than intuition alone in identifying risks. General systems theory offers a variety of analytic techniques that help identify risk in a system. The techniques include diagramming three-dimensional node and link, building association matrices, and conducting critical node analysis.[47] Developing a general systems perspective during analysis can help identify and mitigate some kinds of risk. Identification of single elements in a system essential to its overall performance, improperly or poorly connected elements, and unnecessary redundancies are example risks for which systems analysis can offer mitigation solutions. The relative success of general systems analysis techniques has made them popular with analysts. However, risk analysis and mitigation using general systems theory has had a few unintended consequences.

Complex adaptive systems analysis can help explain the shortcomings of general systems analysis. In an effort to mitigate risk against system stressors, general system theory solutions tend to distribute stress equally across tightly coupled and uniform components.[48] Power grids, a

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the museum's website, which cites a series of memos written by J.C.R. Licklider, the first head of the computer research program at ARPA.

[47]Ludwig von Bertalanffy, *General Systems Theory: Foundations, Development, Applications* (New York: George Braziller, 1968), 195; Department of Defense, *Joint Publication 2-01.3*, II-44. The joint pub details the techniques quite well, although they trace back to Bertalanffy's original work.

[48]Axelrod and Cohen, *Harnessing Complexity*, 108.

kind of information system, built in the 1970s when general systems analysis had become pervasive are a good example. The result of risk mitigation efforts were fewer local outages, but cascades of larger outages, such as the 1977 New York blackouts and two during 1996 in the western United States. The corrective response to the power grid failures, now federally mandated, is Smart Grid.[49]

Smart Grid uses computer-based remote control and automation for the networks that carry electricity from the generation plants to consumers. Before Smart Grid, the power grid components were more or less static, requiring time and labor to make adjustments that reacted much slower than the changing demands on the network. With Smart Grid, each device on the network—building blocks—has sensors to gather data—measuring fitness criteria—plus two-way communication between the device in the field and the utility's network operations center—relationships and information flow. A key feature of the smart grid is automation technology—a response profile—that lets the utility adjust and control each individual device—creating adaptive agents based on assessment of fitness—from a central location. In addition to improved reliability, the Department of Energy states Smart Grids "offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices."[50]

Smart Grid improves electrical power reliability and service by understanding, describing, and assessing the flow of energy in the power grid more accurately and adapting the system to meet shifting demand. The increased accuracy comes from adding measurements of relevant information that bear on system behavior. Allowing diversity in the building blocks,

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[49]Office of Electricity Delivery & Energy Reliability, *Smart Grid* (2013). http://energy.gov/oe/technology-development/smart-grid (accessed 12 September 2013).

[50]Ibid.

identity tags, response profiles, and fitness criteria for elements in the system make a system less susceptible to a single source of stress. Allowing natural growth within a system—something like a balanced ecological system—reduces the likelihood of eventual stressors adding up to a catastrophe.[51] Likewise, complex adaptive systems analysis attempts to represent social systems more accurately than general system theory by adding concepts that meaningfully bear on the system's behavior.

Such analytic explanations are interesting and encouraging. What is missing from these suggestions, and complex adaptive theory in general, is comprehensive, long-term field-testing. While an improvement over raw intuition at solving problems and mitigating risk, general systems analysis is still subject to failures. This point should cause one to wonder about the limitations of complex adaptive system analysis. One must use a tool and use it hard to find out how it breaks. Complex adaptive systems analysis holds promising potential, but so did intuition and general systems theory before extensive trial and failure in large non-linear systems.[52] Risk analysis is prone to the risk of failure itself, with or without the benefit of massive data sets, trend analysis, and new analytic techniques.[53]

When complex adaptive systems analysis misidentifies risk, the results can be confounding. Such systems are nonlinear and understanding cause-effect relationships in complex environments is extraordinarily difficult. Efforts to identify and mitigate risk may have little

[51]Page, *Understanding Complexity*, 47.

[52]Garry A. Klein has published many works exploring and validating intuitive decision-making. Klein's findings are helpful for understanding intuition, especially the commander role in the JOPP. However, for this discussion, the scale and dispersion of the non-linear systems that commanders face require systemic analytic support to inform intuitive decision-making.

[53]See Nassim N. Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007).

effect on the system, or at times worse, have too much or unintentional effect.[54] The solution to such befuddling failure sometimes witnesses a return to the primitive roots of analysis. The blame intuitively lands upon an individual or two—usually executives or officers—whom become cathartic scapegoats. Strangely, the same credit does not come with inexplicable success.[55]

To sum up, this information systems examination has illustrated a few points. The first point is risk is always present, is in part manageable, and no form of risk analysis is infallible. The second is risk analysis improves step by step from basic human intuition, to systems analysis, and then complex adaptive systems analysis. The third point is complex adaptive systems analysis is the best available option for now, but perhaps something even better will come along in the future. Having completed the exploration of risk with this information system example, the discussion turns to evaluation.

Looking back across the iterative prisoner's dilemma, the health care executive education programs, and the examination of risk analysis in information systems examples, how have concepts from complex adaptive systems improved understanding, visualizing, describing, and assessing? Understanding improved in all three examples. In the first example, the iterative prisoner's dilemma—often used as a kind of false start point to understand social systems—proved to behave more like reality for social interaction. The six concepts from complex adaptive system theory, when applied in a computer simulation, produced much more telling and

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[54]Scott E. Page, "Understanding Complexity," *The Great Courses*, 27.

[55]"Transcript: Vice President Gore on CNN's 'Late Edition'," CNN News (March 1999). http://www.cnn.com/ALLPOLITICS/stories/1999/03/09/president.2000/transcript.gore/ index.html (accessed 11 June 2013). Al Gore tried to take credit for such inexplicable success in a complex adaptive system when he said, "During my service in the United States Congress, I took the initiative in creating the Internet. I took the initiative in moving forward a whole range of initiatives that have proven to be important to our country's economic growth and environmental protection, improvements in our educational system." The statement is often lampooned as Gore claiming to have invented the internet.

satisfying results. Participants from the health care system provide feedback that incorporating complex adaptive systems concepts in health care improved their understanding of the system, improving the quality of health care. The third example demonstrated that understanding of risk improves with the six concepts.

Visualization also improves with the inclusion of the six concepts. While the iterative prisoner’s dilemma had little to offer for visualizing change in an environment, the health care professionals were able to turn their understanding of the health care system into changes that benefitted patients and the emergent phenomena of health care for the individual. Likewise, better risk analysis helped make information systems more reliable and less prone to certain causes of catastrophic failure. In many cases, including concepts from complexity when thinking about a system generates new approaches to problem identification and solution.

Description is perhaps the most improved of the evaluation criteria. With the inclusion of the six concepts from complex adaptive system theory, the modeler as well as his readers could understand the experimental results of neighborhoods forming in the iterative prisoner’s dilemma. Similarly, describing the efforts and impacts of health care system changes and risk mitigation in information systems without the conceptual tools of complex adaptive systems is difficult to imagine. By including the concepts, the understanding and visualization developed by the observers of the systems could be described more fully to others.

The evaluation criterion of assessment improved for the same reasons understanding improved. The improvement makes sense in that assessment is in some ways a post-facto understanding of the system. If understanding can improve, assessment will as well. For all four evaluation criteria, the three examples demonstrate the utility and efficacy of incorporating concepts from complex adaptive systems theory into analysis. In each, complex adaptive systems concepts improved understanding, visualization, description, and assessment. In that analogous situations can function as precedent for new, unfamiliar ones, how might these lessons translate to the JOPP?

CONVEYING THE COMPLEX

The examples of the helpful side of complexity lead to some interesting insights into the potential of complex adaptive systems theory for U.S. Joint Force doctrinal operations processes. Social systems are inherently complex adaptive systems. The common use of social systems analysis across U.S. Joint Force operations processes narrows the focus for application of complex adaptive systems theory. Three central operations planning processes use social systems analysis. The joint intelligence preparation of the operational environment provides information about the operational environment. Operational design defines the operational problem and formulates an operational approach to solve the problem. The joint personnel planning process develops capability through a Joint Force structure to solve the problem. A constant challenge for social systems analysis in the JOPP is the limitations of general systems theory in conveying the full understanding of the analysts. Concepts from complex adaptive systems theory might help make these social systems analysis processes better.

Six concepts from complex adaptive systems theory—fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent phenomena—have the potential to improve social systems analysis in doctrinal operations processes, which in turn support four of the six commander activities—understand, visualize, describe, and assess—within the U.S. Joint Force. The six concepts from complex adaptive system theory have improved other analogous, non-military processes. Concepts from complex adaptive systems cause computer-based social analysis to be more consistent with observations of human social situations. Educating health care executives to the complex adaptive qualities of the health care system helped them to not only understand, visualize, describe and assess the health care system better, but also to lead and direct more effectively. When left to examine risk without empirical data, complex adaptive systems theory improved risk analysis over techniques such as intuition and general systems analysis. However, complexity-based risk analysis currently lacks comprehensive, long-term field-testing and may have unidentified failures of its own.

With these insights in hand, the next question for the operational designer is where we are going. More precisely, if social systems analysis were to employ the concepts from complex adaptive systems theory, how might it be done? Fortunately, Joint doctrine provides a solid base upon which to set these six concepts. Joint doctrine already includes a concise, practical guide to general systems analysis in Joint Publication 2-01.3: *Joint Intelligence Preparation of the Operational Environment.*[56] Just as complex adaptive systems theory builds upon general systems theory, the six concepts could build upon the existing doctrine. Found only in one joint publication, the JIPOE offers a node and link methodology to construct a systems perspective of the operational environment. As mentioned earlier, the nodes are agents and the links are relationships in social systems analysis. The systems analysis method in the JIPOE includes constructing three-dimensional diagrams of nodes and links across six subdivisions of the operational environment, analyzing relationships, and evaluating their impacts on military operations.

To change general systems to complex adaptive systems requires—at a minimum—including the six concepts from complex adaptive systems into social systems analysis. However, their inclusion must be from a true systems perspective, where agents have diversity, connection, interdependence, and adaptation. Accomplishing analysis that is more than a block check requires thinking from a holistic, synthetic systems perspective. For an example of employing concepts without such a perspective, consider how general system theory brought about the operational

[56]Department of Defense, Joint Publication 2-01.3, II-44.

variables, also called PMESII (Political, Military, Economic, Social, Infrastructure, and Information). The operational variables are supposed to describe a system of interrelated variables that make up the operational environment. Problematically, some employ the operational variables without a system perspective, relegating them to merely a checklist of PowerPoint slides. Employing the six concepts from complex adaptive systems ought not fall victim to the same problematic employment.

If the six concepts are included in the methodology of the JIPOE in a holistic, synthetic systems perspective, analysts could improve their own understanding of the operational environment and describe it in more meaningful detail. Further, using the six concepts could help operational planners visualize and describe an operational approach in the operational design process, improving the information commanders use to make decisions. Such employment would be the beginning of an update of systems analysis doctrine from general systems theory to complex adaptive systems theory.

Including the six concepts from complex adaptive systems theory brings two new considerations for the analyst: the meaning of the concepts across multiple frames of reference and the construction of link diagrams. Having consistency and agreement in the meaning of terms—called intersubjectivity—is important as concrete examples fill in the blanks provided by the abstract concepts.[57] What kinds of things are agents for example? From a particular frame of reference, agents may be nation-states. In another, agents may be military units or nongovernmental agencies. Specifying the specific agent types for analysis sounds like a simple thing to accomplish, but can get confusing very quickly. Part of the cause of the confusion is the interaction between frames of reference coupled with the possible fractal consistency between

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[57]Paul Davidson Reynolds, *A Primer in Theory Construction* (Boston: Allyn and Bacon Classics, 2007), 12.

those frames.[58] A technique to cope with the potentially confusing intersubjectivity is to construct a chart.

System Component	Strategic Frame	Operational Frame	Tactical Frame
Agent	Nation, Department of Defense, International Organization	Fielded Force, Population Center, Key Leader	Person, Council, Social Group
Agent Fitness	GDP, Border Integrity, International Access and Influence	Elements of Combat Power	Maslow's Hierarchy of Needs, Political Power, Wealth
Agent Response Profile	Socio-Cultural Factors, Political Goals, Ends-Ways-Means	Doctrinal Templates, Situational Templates	Game Theory, Agent-Based Modeling, Intelligence Profiling
Identity Tags	Commander-in-Chief, Ambassador, NGO Director, CEO	Unit Designators, Call Signs, Uniforms, Weapons Systems	Language, Attire, Tribal Affiliation
Relationships	Alliance, Sanction, Favored Nation, War	Elements of Decisive Action	Subordinate, Friend, Kin, Enemy
Physical Links	Embassy Activity, Talks, Integrated Networks	Battle, Key Leader Engagement, Wide Area Network	Conversation, Telephone, Network Access Point
Exchanges	Legitimacy, Debt, Trade, Information Sharing Agreements	Violence, Threat of Violence, Operational Support, Intelligence Sharing	Authority, Wealth, Violence, Information
Building Blocks	Elements of National Power (DIME), National Capability (DOTMLPF)	Operational Variables (PMESII), Elements of Operational Art	Ideas, Tactics, Techniques, Technologies
Fitness Function	International Position of Relative Disadvantage	The Multi-facets of Military Defeat	Bankruptcy, Exile, Death
Emergent Phenomena	World Superpower, Independent State, Pariah State	Regional Stability, Insurgency, Anarchy	Informal Leadership, Public Opinion

Chart 1: Political-Military Examples for Complex Social System Analysis Components

Source: Created by author.

[58]Benoit B. Mandelbrot, *The Fractal Geometry of Nature* (New York: W.H. Freeman and Company, 1982), 44.

Along one axis of the chart—across the top—would be the frames of reference that are of concern for the analysis. Along the other axis—down the left side—would be the eight abstract concepts, which include agents and relationships plus the new six. Chart 1: Political-Military Examples for Complex Social System Analysis Components provides some example items one might consider for such a chart, although specific items would be dependent upon the analytic frame of reference. The use of a chart helps to establish consistency and intersubjectivity for the concepts within a particular analytic frame of reference. However, other methods may be equally helpful in maintaining consistent meaning.

A second consideration comes into play for link diagrams. A link diagram is a graphical representation of a system. With just the two concepts from general systems theory, these link diagrams can become complicated to the point of illegibility, perhaps becoming the dreaded spaghetti diagram. Adding in six more concepts will make the problem worse, but not every concept need apply uniformly across the diagram if it is not helpful. While analysts ought to consider all the concepts, the link diagrams need only include those elements necessary to understand the system.[59] A generic three-agent link diagram of a complex social system analysis might look similar to Figure 1: A Generic Complex Social Systems Analysis on the following page.

To further reduce the possible mess of an eight-concept link diagram, analysts can split the diagrams by frames of reference. Thus, each frame of reference would have its own link diagram, perhaps one for the strategic frame and one for the operational for example. Dividing the diagrams by frames of reference may also help preserve consistency and intersubjectivity. Whatever techniques analysts choose, the link diagrams should stay legible and useful to as broad

[59]See Peter Checkland and John Poulter, *Learning for Action: A Short Definitive Account of Soft Systems Methodology and Its Use for Practitioners, Teachers, and Students* (West Sussex: John Wiley & Sons, 2006).

an audience as possible so the analytic products continue to help the staff at large understand, visualize, describe, and assess the system.

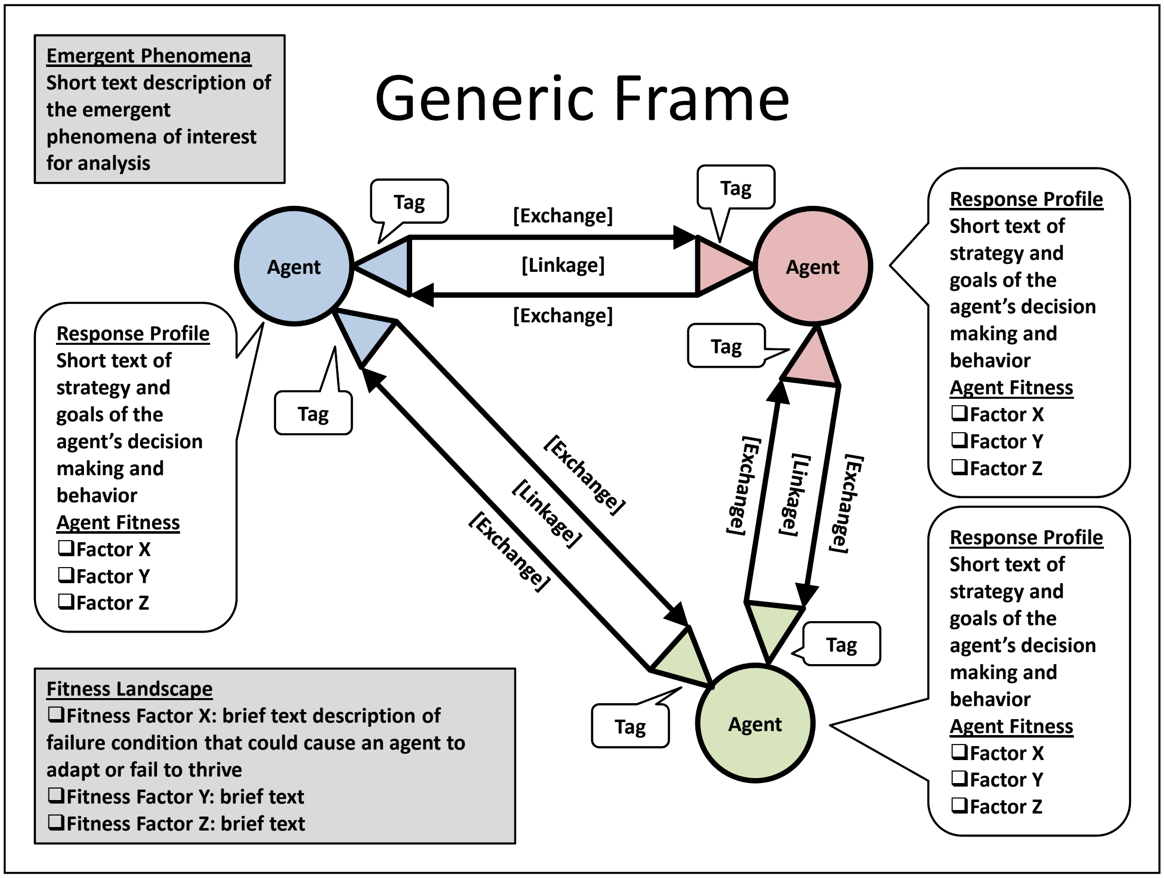

Figure 1: A Generic Complex Social Systems Analysis

Source: Created by author.

To help improve the usefulness of the analysis as it transits the analytic and JOPP processes, analysts should also consider including a concise narrative explaining the highlights of the chart and link diagrams. After analyzing the system with the chart and link diagrams, a written narrative helps communicate the meaning of the analysis to other staff members. Joint doctrine mentions the use of narratives, and for good reason. Narratives have their flaws, but are the best alternative for connecting reality, interpretation, representation, and persuasion.[60] The act of writing a concise narrative is also an effective way to check the consistency and meaningfulness of the analysis underpinning it.

To conclude this section, understanding, visualization, description, and assessment of social systems can improve by adding the six concepts from complex adaptive systems to the two from general systems theory. The six concepts— fitness landscape, agent fitness, agent response profiles, building blocks, identity tags, and emergent phenomena—could be included with the existing general systems analytic methodology described in Joint Publication 2-01.3: *Joint Intelligence Preparation of the Operational Environment*, Chapter II, Section B, Part 12. The addition of the six concepts stands a good chance of making the analytic products more difficult to communicate to others as the information included on the products grows. However, three techniques mitigate this potential hazard: a chart to establish intersubjectivity by frame of reference, a separate link diagram per frame of reference, and a concise narrative to explain the most salient points of the analysis. Although a complex adaptive systems perspective of the operational environment adds six new concepts to the existing two, the careful employment of the concepts into existing doctrinal processes can keep it helpful.

IMPLICATIONS AND RECOMMENDATIONS

Concepts from complexity can help make the U.S. Joint Force more effective. The discussion began by looking broadly across Joint operational processes, gradually narrowing to the JOPP, and ultimately pointing at a specific section of the JIPOE. However, the benefits of updating the general systems analytic methodology to one of complex adaptive systems should trace backwards from the JIPOE, back to the JOPP, and to the staff that supports the commander.

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[60] John Lewis Gaddis, *The Landscape of History: How Historians Map the Past* (Oxford: Oxford University Press, 2002), 10-11, 15, 45.

Joint staff members, such as those of the J-1 and J-5 staff sections, can benefit from updating systems analysis in Joint doctrine as much as any analyst using JIPOE. As the earlier description of social systems analysis in doctrine showed, Joint personnel planners could employ systems thinking to analyze the conversion of resources into capabilities for a tailored U.S. Joint Force in a more explicit way, for instance. Another instance is operational designers could employ complex adaptive systems analysis for operational design. The implication is that complex adaptive systems analysis can help a wide swath of operational processes and the swath extends beyond the J-2 staff section.

Including the six concepts from complex adaptive systems theory to U.S. Joint Force doctrine is simply a start to updating Joint doctrine to include complexity. A full update of the doctrine from a general systems theory basis to that of complex adaptive systems, which this monograph recommends, requires much more. Further research could identify other opportunities to bring helpful complexity to the U.S. Joint Force. One should look outside of typical sources of inspiration to better cope with complexity.

Complexity and coping mechanisms for complexity can crop up in a variety of places, some expected and others much less so. A fair number of sources offer analytic techniques or simply a new perspective for complex adaptive systems. One example is *Truth in Comedy: The Manual for Improvisation*, which includes an explanation of the mechanics behind and tips for improvisational comedy.[61] Although a nonstandard source for military advice, this book presents key points at the end of each chapter that are quite helpful as operating guidelines within complex adaptive systems. Words synonymous with effectiveness must replace words such as funny and humor, however. While less novel, Thomas Czerwinski's *Coping with the Bounds: Speculations*

[61]See Charna Halpern, Del Close, and Kim "Howard" Johnson, *Truth in Comedy: The Manual for Improvisation* (Colorado Springs: Meriwether, 1994).

on Nonlinearity in Military Affairs is one that offers heuristic methods and has a fair number of fans.[62] Jamshid Gharajedaghi also offers some help in *Systems Thinking: Managing Chaos and Complexity*. Chapters 5 and 6 from Gharajedaghi's work could easily join the systems analysis doctrine in *JP 2-01.3*. Sufficed it to say, there are plenty of places to look for further research on updating Joint doctrine with ideas from complexity.

In summation, this monograph introduced concepts from complexity, demonstrated their efficacy, and described ways in which they could be included into operations. The implication for those Joint staff sections beyond the J-2 is to adopt and use the JIPOE systems doctrine for their own staff sections. The operations process as a whole just might see improvement. The recommendation was to continue to research and incorporate helpful complexity into U.S. Joint Force doctrine. The author would like to offer a final thought for the still skeptical reader. Systems thinking and complexity may seem overwhelming, intimidating, and confounding, but that does not make the insights offered by complexity science any less relevant.

[62]See Thomas J. Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs* (Washington D.C.: Institute for National Strategic Studies at the National Defense University, 1998).

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